PART 11

EXTREMITIES

CHAPTER 54

Peripheral Vascular Disease

KEY TEACHING POINTS

- By analysis of the patient's symptoms, examination of the patient's pulses, and knowledge of the anatomy of peripheral vascular disease, clinicians can accurately diagnose the distribution and severity of a patient's vascular disease.
- Peripheral vascular disease affects three distinct anatomic segments: aortoiliac, femoropopliteal, and peroneotibial. Disease of a single segment causes claudication; disease of multiple segments causes rest pain and limb-threatening ischemia. Only patients with diabetes or thromboangiitis obliterans develop disease in the peroneotibial segment.
- In patients with claudication, the following signs increase the probability of peripheral vascular disease: absence of both pedal pulses, presence of foot wounds or sores, absence of femoral pulses, asymmetric coolness, and presence of a limb bruit.
- In critically ill patients, three signs of reduced peripheral perfusion—cool limbs, capillary refill time of more than 5 seconds, and mottling of the skin—increase probability of a reduced cardiac output and adverse outcome.

I. INTRODUCTION

Chronic arterial disease usually affects the lower limbs in three distinct segments: (1) the aortoiliac segment (especially the infrarenal abdominal aorta and common iliac arteries), (2) the femoropopliteal segment (especially the superficial femoral artery in the adductor canal), and (3) the peroneotibial segment (below the knee).[1] Disease in each segment produces distinct patterns of claudication (Table 54.1). Most patients have aortoiliac disease, femoropopliteal disease, or both.[2] Disease below the knee is uncommon unless the patient is diabetic or has thromboangiitis obliterans.

The diagnostic standard for chronic lower-extremity ischemia is the ankle-brachial blood pressure index (ABI), which is obtained by positioning the patient

TABLE 54.1 Diagnosis of Peripheral Arterial Disease: Traditional Approach

Anatomic segment	Location of claudication	PULSE EXAMINATION		
		Femoral	Popliteal	Pedal
Aortoiliac	Buttock, thigh, calf†	Absent	Absent	Absent
Femoropopliteal*	Calf	Present	Absent	Absent
Peroneotibial	None or foot‡	Present	Present	Absent

*The *femoro* of femoropopliteal indicates the superficial femoral artery; the *femoral* of femoral pulse indicates the common femoral artery.
†May cause erectile dysfunction if internal iliac arteries are involved.
‡Disease in this segment usually causes no claudication in patients with diabetes but causes foot pain in those with thromboangiitis obliterans (Buerger disease).
Based upon reference 1.

supine and measuring the highest systolic blood pressure at the ankle (dorsalis pedis and posterior tibial arteries), using a handheld Doppler flow meter, and dividing it by the blood pressure in the brachial artery.[3]* Values less than 0.97 are abnormal (i.e., the lower 2.5% of measurements from large numbers of young, nonsmoking, asymptomatic persons),[4-6] although most investigators define chronic leg ischemia as an ABI less than 0.9.[3] Most patients with claudication have ABIs between 0.5 and 0.8 and disease in only a single segment; those with limb-threatening ischemia (i.e., rest pain, gangrene) have ABIs less than 0.5 and disease in at least two segments.[5,6]

II. THE FINDINGS

A. APPEARANCE OF THE FOOT

The earliest clinicians writing about peripheral vascular disease emphasized the physical sign of gangrene, but in 1924 the American surgeon Leo Buerger described in his book *The Circulatory Disturbances of the Extremities* various *prodromal signs* of vascular disease, including toe and foot ulcers, poor capillary refill, impaired nail growth, atrophic skin, foot pallor with elevation, and dependent foot rubor (i.e., redness of the foot first appearing after dangling it in a dependent position, i.e., over the edge of a bed).[7] Clinicians have since regarded these findings as characteristic of chronic lower limb ischemia, although some of them—especially poor capillary refill and dependent rubor—were controversial even in Buerger's time.[8,9]

B. PULSES

In studies of large numbers of healthy individuals, the dorsalis pedis pulse is not palpable 3% to 14% of the time and the posterior tibial pulse is not palpable 0% to 10% of the time.[10-15] Nonetheless, when one of these arteries is congenitally small

*The blood pressure cuff should be placed just above the ankle, wrapping the cuff's edges parallel to each other (*spiral* wrapping increases interobserver disagreement). Oscillometric blood pressure cuffs (i.e., automated blood pressure cuffs) should *not* be used because they tend to overestimate pedal pressure (3).

or absent, the other enlarges to make up the difference, explaining why only 0% to 2% of healthy persons lack *both* pedal pulses.[10,11,14]

The absence of both pedal pulses is common to vascular disease in each of the three vascular segments and thus represents the best screening test for peripheral vascular disease (see Table 54.1).

C. BRUITS

A traditional finding of vessel stenosis is the limb bruit, either iliac (above the inguinal crease), femoral (in the thigh), or popliteal. Complete occlusion of a vessel should make bruits disappear.

In patients who have undergone femoral artery puncture for cardiac catheterization, the presence of a continuous femoral bruit (i.e., one extending beyond the second heart sound and thus having both systolic and diastolic components) suggests an abnormal communication between an artery and vein (i.e., arteriovenous fistula, see Chapter 43).

D. ANCILLARY TESTS

1. VENOUS FILLING TIME

In patients with peripheral vascular disease, the veins of the feet fill abnormally slowly after they are emptied. After positioning the patient supine and identifying a prominent vein on the top of the foot, the clinician empties this vein by elevating the patient's leg to 45 degrees above the table surface for 1 minute. The patient then sits up and dangles the foot over the edge of the examining table, the clinician then recording how long it takes for the vein to rise above the level of the skin surface. Measurements of more than 20 seconds are abnormal.[16]

2. CAPILLARY REFILL TIME

Normal values of capillary refill time, based on observation of thousands of persons, average approximately 2 seconds.[17,18] Women have slightly longer times compared with men, and capillary refill times normally increase in elderly patients and in cooler ambient temperatures.

In the studies of capillary refill of patients with suspected peripheral vascular disease, investigators applied firm pressure for 5 seconds to the plantar skin of the great toe and then timed how long it took for normal skin color to return after releasing the pressure. Measurements of 5 seconds or more were regarded abnormal.[16] In studies of capillary refill of critically ill patients, investigators tested the patient's finger (usually index finger) by applying firm pressure for 15 seconds and regarded times of 5 seconds or more as abnormal.[19-21]

3. BUERGER TEST

In the Buerger test, the clinician observes the color of the patient's leg when it is elevated and again when lowered. Abnormal pallor with elevation and a deep rubor in the lowered position are features of vascular disease.[1,7] In Buerger's version of the test, the clinician elevated the leg to produce pallor and then simply recorded the angle at which the reddish hue returned as the limb was lowered (his *angle of circulatory sufficiency*).[7] In the only investigated version of this test (see section on Distribution of Vascular Disease), the clinician elevated the patient's leg 90 degrees from the table surface for 2 minutes and then dangled it perpendicular to the table edge for another 2 minutes. The positive response was abnormal pallor with elevation and the appearance of a dusky red flush spreading proximally from the toes in the dependent position.[22]

III. CLINICAL SIGNIFICANCE

A. DIAGNOSIS OF PERIPHERAL VASCULAR DISEASE

EBM Box 54.1 shows that the following physical signs *increase* the probability of peripheral vascular disease (i.e., ABI < 0.9) if found in a symptomatic leg: absence of both pedal pulses (likelihood ratio [LR] = 8.8), presence of wounds or sores on the foot (LR = 7), absence of femoral pulse (LR = 6.1), presence of asymmetric coolness of the foot (LR = 6.1), and presence of any limb bruit (LR = 5.6). In another study[16] the presence of foot coolness was diagnostically unhelpful, although

EBM BOX 54.1
*Peripheral Vascular Disease**

Finding (Reference)†	*Sensitivity (%)*	*Specificity (%)*	Likelihood Ratio‡ if Finding Is	
			Present	*Absent*
Inspection				
Wounds or sores on foot[23]	2	100	**7.0**	NS
Foot color abnormally pale, red, or blue[23]	35	87	2.8	0.7
Atrophic skin[16]	50	70	1.7	NS
Absent lower limb hair[16]	48	71	1.7	NS
Palpation				
Foot asymmetrically cooler[23]	10	98	**6.1**	0.9
Absent femoral pulse[23]	7	99	**6.1**	NS
Absent posterior tibial and dorsalis pedis pulses[23-25]	63-73	91-99	**8.8**	**0.3**
Auscultation				
Limb bruit present[23,25-27]	20-50	92-99	**5.6**	0.7
Ancillary tests				
Capillary refill time ≥5 s[16]	28	85	1.9	NS
Venous filling time >20 s[16]	22	94	**3.6**	NS

*Diagnostic standard: For *peripheral vascular disease*, ankle-brachial index <0.8-0.97 except for the study by Boyko[16] (i.e., atrophic skin, absent lower limb hair, capillary refill time, and venous filling time), which recruited only diabetic patients and defined disease as ABI <0.5.
†Definition of findings: for *limb bruit present*, femoral artery bruit[23,25,27] or iliac, femoral, or popliteal bruit.[26]
‡Likelihood ratio (LR) if finding present = positive LR; LR if finding absent = negative LR.
NS, Not significant.
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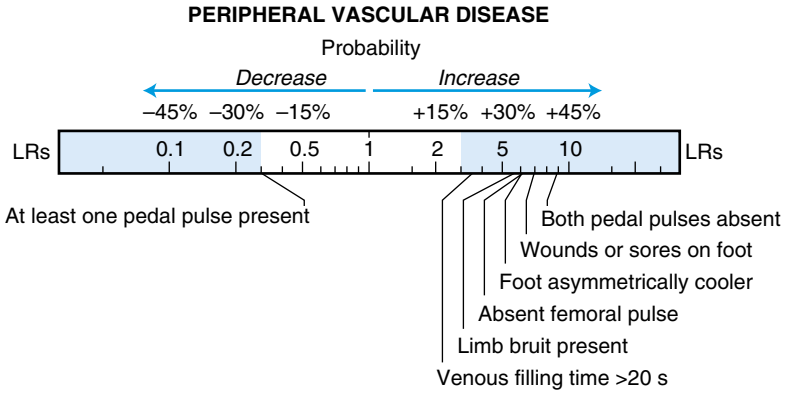

this study defined the abnormal finding as "foot cooler than ipsilateral calf," which actually is a normal finding (i.e., the skin surface temperature of healthy persons normally diminishes toward the feet, paralleling progressively reduced cutaneous blood flow to conserve body heat).[1]

The only finding that *decreases* the probability of peripheral vascular disease is the presence of one or both pedal pulses (LR = 0.3), although studies show that up to one of three patients with disease have this finding. In these patients, however, the pulses often diminish or disappear during exercise (e.g., running in place, walking, toe-stands, or ankle flexion repeatedly against resistance), just as normal resting coronary blood flow in a patient with coronary artery disease may become abnormal after exercise.[3,28]

Findings that are unhelpful diagnostically are atrophic skin, hairless lower limbs,[29,30] and prolonged capillary refill time. Writing soon after Buerger introduced the capillary refill time as a test of peripheral vascular disease (his *expression test*), Lewis[9] and Pickering[8] showed it was an unreliable sign because prompt refill could occur from the veins of a limb rendered completely ischemic experimentally. However, in critically ill patients a prolonged capillary refill time in the patient's finger does have proven diagnostic value (see Section on Detecting Hypoperfusion in Intensive Care Unit).

Some investigators have wondered whether clinicians could accurately measure the ABI by palpating the pedal pulses distal to the blood pressure cuff instead of using a Doppler flowmeter. In one study,[31] such an ABI less than 0.9 *by palpation* detected an ABI less than 0.9 by *Doppler testing* with a sensitivity of 88%, specificity of 82%, positive likelihood ratio [LR] = 5, and negative LR = 0.2. Another innovative way to detect peripheral vascular disease (without Doppler) places a bedside pulse oximeter sequentially on the patient's fingers and great toes: a positive result is either a supine toe measurement 2% lower than the finger measurement *or* a toe measurement that decreases 2% after 12 inches of foot elevation. This test detects vascular disease with a sensitivity of 77%, specificity of 97%, positive LR = 30.5, and negative LR = 0.2.[32] Nonetheless, studies of ABI by palpation and toe pulse oximetry have enrolled mostly asymptomatic patients, and it is unlikely these tests would be easy to apply in patients with more serious vascular disease, who may lack pedal pulses or have undetectable toe arterial waveforms.

B. DISTRIBUTION OF PERIPHERAL VASCULAR DISEASE

One study showed that vascular surgeons using traditional methods accurately localized the distribution of disease in 96% of 102 symptomatic patients, although the study omitted information about the relative value of specific findings.[33] Of the few studies available, one confirms the traditional teaching (Table 54.1) that an absent or severely diminished femoral pulse in a symptomatic limb increases probability of aortoiliac disease (sensitivity = 39%, specificity = 99%, positive LR = 31, negative LR = 0.6).[34] In addition, in symptomatic limbs with preserved popliteal pulses (i.e., a finding arguing against *occlusion* of the aortoiliac or femoropopliteal segments), the presence of a limb bruit argues *for* the presence of stenoses on angiography, a finding of therapeutic importance because these patients may be candidates for angioplasty (sensitivity = 80%, specificity = 75%, positive LR = 3.2, negative LR = 0.3).[35] Finally, patients who have a positive Buerger test have more extensive disease than those who are test negative, including more rest pain (60% versus 8%) and gangrene (23% versus 0%) and lower ABIs (mean ± standard deviation [SD], 0.37 ± 0.29 versus 0.62 ± 0.23).[22]

C. COMPLICATIONS OF ARTERIAL PUNCTURE

Femoral artery puncture for cardiac catheterization may rarely be complicated by the formation of false aneurysms or arteriovenous fistulae. In one study of patients with significant groin hematomas or new limb bruits after cardiac catheterization, two findings were diagnostic.[36] A **continuous femoral bruit** (i.e., one having both systolic and diastolic components) was diagnostic for arteriovenous fistula (sensitivity = 96%, specificity = 99%, positive LR = 80.8, negative LR = 0.04), and an **expansile femoral pulsation** (i.e., a dilated arterial pulsation whose walls expanded laterally with each beat) was diagnostic for false aneurysm formation (sensitivity = 92%, specificity = 93%, positive LR = 13.8, negative LR = 0.1). In this study the diagnostic standard was duplex scanning, surgery, or both.

D. DETECTING HYPOPERFUSION IN INTENSIVE CARE UNIT

The body normally responds to decreased cardiac output by reducing cutaneous blood flow to the skin, which may produce cool limbs, longer capillary refill times, and mottling of the limbs (mottling is a blotchy or lacelike pattern of dusky erythema). In patients with critical illness, each of these signs, alone or in combination, identifies patients with reduced cardiac output, worse prognosis, or both. For example, the finding of cool legs in intensive care unit (ICU) patients increases the probability of low cardiac output (LR = 3.7; EBM Box 54.2), even in the subset of patients with sepsis (LR = 5.2). A capillary refill time of 5 seconds or more predicts major postoperative complications after intra-abdominal surgery (LR = 12.1) and predicts 14-day mortality in patients with sepsis (LR = 4.6). Mottling of the skin over the knees also predicts mortality in patients with sepsis (LR = 13.4), independent of the use of vasopressor medications, and its course over time heralds the patient's outcome (i.e., patients whose mottling diminishes over time have better survival than those whose mottling persists).[39]

Other investigators have focused on combinations of findings. For example, in one study of intubated patients with acute lung injury, the simultaneous presence of capillary refill time more than 2 seconds,[†] mottling over the knees, and cool limbs increased the probability of low cardiac output (LR = 7.5). In another series of ICU

[†] This study contrasts with other studies of capillary refill by applying only *mild* pressure on the patient's fingertip to elicit the finding, not firm pressure, and by defining the abnormal test as just 2 seconds or more.

EBM BOX 54.2
*Peripheral Perfusion of ICU Patients**

Finding (Reference)†	Sensitivity (%)	Specificity (%)	Likelihood Ratio‡ if Finding Is Present	Likelihood Ratio‡ if Finding Is Absent
Detecting Low Cardiac Output				
Both legs cool (all patients)[37]	23	94	**3.7**	0.8
Both legs cool (patients with sepsis) [37]	30	94	**5.2**	0.7
Combinations of Hypoperfusion Findings[38]				
0 of 3 findings present	36	24	0.5	—
1 of 3 findings present	52	—	2.3	—
3 of 3 findings present	12	98	**7.5**	—
Detecting Elevated Arterial Lactate Level				
Limb is cool or capillary refill time ≥5 s[19]	67	69	2.2	0.5
Predicting Multiorgan Dysfunction				
Limb is cool or capillary refill time ≥5 s[19]	77	70	2.6	**0.3**
Predicting Major Postoperative Complications After Intra-Abdominal Surgery				
Capillary refill time ≥5 s[20]	79	93	**12.1**	**0.2**
Predicting 14-Day Mortality if Septic Shock				
Capillary refill time ≥5 s[21]	50	89	**4.6**	0.6
Mottling of skin over knees[39]	41	97	**13.4**	0.6

*Diagnostic standard: For *low cardiac output, cardiac index* <2.5 L/min per m^2 [38] or <3 L/min per m^2 [37], for *elevated lactate level,* blood lactate >2 mmol/L; for *multiorgan dysfunction,* SOFA score that increases during the first 48 hours of hospitalization (SOFA score is the Sequential Organ Failure Assessment, a score tabulating the following variables: P_aO_2/F_iO_2, number of vasoactive pressors being administered, bilirubin, platelet count, Glasgow coma scale, and creatinine or urine output); for *major postoperative complication*, one requiring endoscopy, repeat surgery, general anesthesia, or ICU transfer.[20]

†Definition of findings: for *both legs cool,* either all four limbs have cool temperature or legs cool despite warm arms (patients with known peripheral vascular disease were excluded)[37]; for *combinations of hypoperfusion findings*, there are three: (1) capillary refill time >2 s, (2) skin mottling over the knees, and (3) cool limbs[38]; for all *capillary refill times*, testing performed on the patient's finger or nailbeds, and; for *mottling of skin over knees,* mottling extending at least to the level of mid-thigh (only light-skinned patients were tested).[39]

‡Likelihood ratio (LR) if finding present = positive LR; LR if finding absent = negative LR.

ICU, Intensive care unit; *NS*, not significant.

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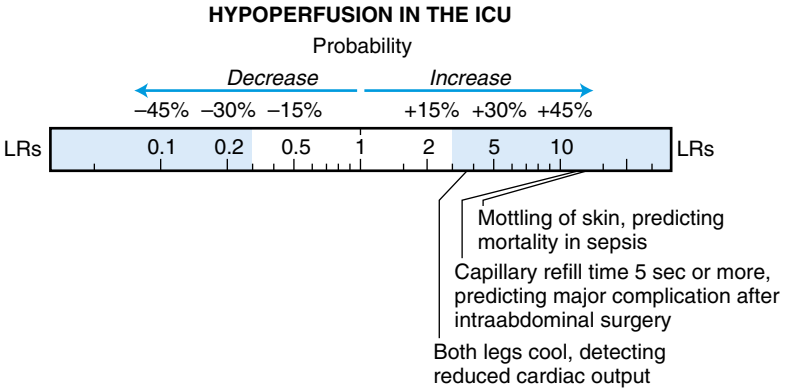

patients, the finding of *either* cool limbs or capillary refill time of 5 seconds or more increased probability of elevated lactate levels (LR = 2.2) and predicted future progressive multiorgan dysfunction (LR = 2.6).

The references for this chapter can be found on www.expertconsult.com.

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